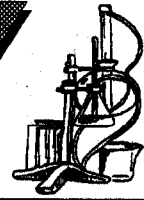


Technology Corner



Number 97-3

UDOT Research News

April 1997

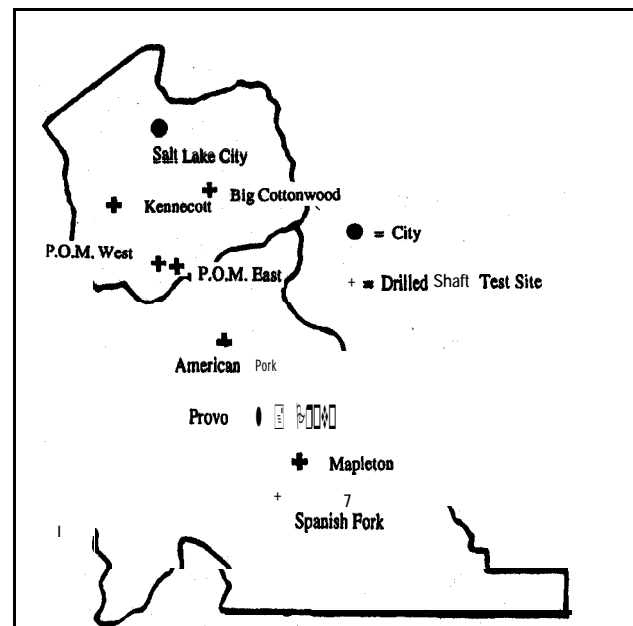
DRILLED SHAFT SIDE FRICTION in GRAVELLY SOILS

PROJECT SUMMARY

This research was conducted by the Civil and Environmental Engineering Department of Brigham Young University under the direction of Professor Kyle M. Rollins for the Research Division of the Utah Department of **Transportation (UDOT)**. The study was to evaluate side friction in gravelly soils or the resistance due to the roughness of the concrete-gravel interface in a drilled shaft foundation. A drilled shaft foundation is constructed by excavating a cylindrical hole in the ground and filling the excavation with concrete, **often reinforced** with steel. When properly designed and constructed, drilled shafts are a reliable, cost-effective, and versatile foundation. Prior research in Utah on **shaft** load testing in gravelly soils indicated that actual shaft capacity was consistently underestimated by present design equations. Generally computed capacities ranged **from** 35 to 75% higher than predicted by current methods and in some cases 4 to 5 time higher. This increase in capacity was thought to result from increased side resistance due to the roughness of concrete-gravel interface. In order to make recommendations regarding the most appropriate design equation and possible modifications to these equations, additional load testing was undertaken where the gravel-concrete side **friction** effect could be isolated. To do this, 28 axial tension (uplift) load tests were performed on drilled shafts in soil profiles ranging from uniform medium sand through well graded sandy gravel. Failure loads were determined **from** load-displacement data using three methods (*double-tangent, slope-tangent, and the 0.5 (12.7mm) displacement*): Load capacities were computed using existing equations (*the FHWA, Meyerhof, and Kulhawy*). Reasonable agreement between measured and computed capacities was generally found in sandy profiles. However, at sites where the gravel fraction was over 50 percent measured capacities were typically 3 to 4 times higher than predicted when using the FHWA equations. Measured capacities were 2 to 4 times higher than predicted by the Meyerhof method. The Kulhawy method was much more conservative than the other two prediction methods. Additional load test data for gravelly **soils** was collected and combined with the data for the Utah load tests. This data was then used to develop **modified** equations for predicting side friction in gravelly soils.

TEST SITES

Eight sites were selected near mountain ranges in Utah. Soil profiles at American Fork, Spanish Fork, Mapleton, and Kennecott consisted of large gravel deposits formed by rivers as they flowed out of mountain canyons into ancient Lake Bonneville that



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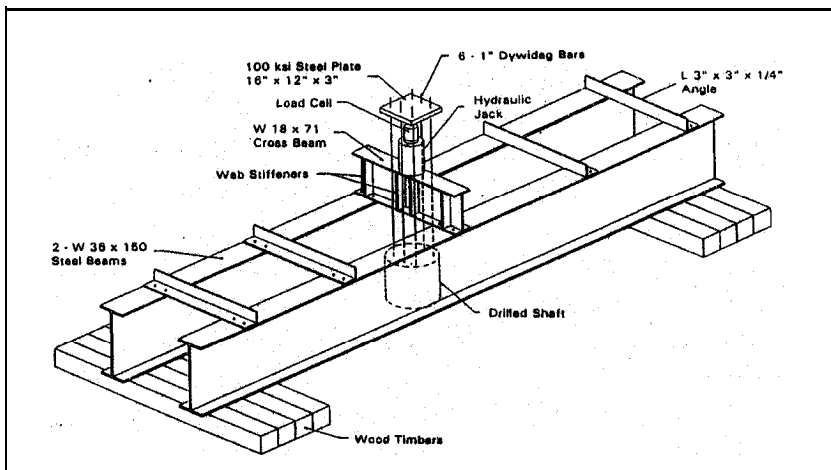
covered the valley floors in northern Utah until the late Pleistocene period. Two exploratory bore holes were drilled to a depth of 20 feet (6 m) at all sites to define the subsurface profile. Borings were generally within 15 ft (4.6 m) of the test shafts. Soil profiles at the eight test sites ranged from uniform medium **grained** sand to well graded sandy gravel with a maximum particle size of 4 inches (100 m).

TEST SHAFT CONSTRUCTION

Test **shafts** were excavated using an 18 inch (460 mm) helical auger and truck mounted drilling equipment. All **shafts** were above the water table and capable of standing open without casing or slurry support. Shaft 5, 10, 15 and 20 feet deep with diameters ranging from 20 and 28 inches (0.5 to 0.7 m) according to depth. Roughness of the shaft walls varied depending on gravel content of the material. Rebar cages were placed in the shafts and concrete was allowed to **free-fall** down the center of the **shaft**. The concrete had a minimum slump of 7 inches (180 mm) and a compressive strength between 3000 and 4500 psi (20.7 and 31 **MPa**) after 28 days.

LOAD TESTING PROCEDURES

Uplift load testing was **performed** with the quick load method as specified by ASTM **D3689-83**. Incremental loading ranging from 0.5 to 15 ton (4.45 to 134 **kN**) were applied and corresponding deflection readings were recorded. A final deflection reading was taken after J-minutes of loading. The shafts were loaded until failure occurred or until the **load-frame** and equipment reached capacity. By using this technique it was possible for the researcher to determine the highest ultimate capacity and then make recommendations for the most appropriate design equations to be used in Utah.



SUMMARY and CONCLUSIONS

Based on the sites evaluated and supported with previous studies the following general conclusion are offered:

- ①. Ultimate side resistance in cohesion less soils increases as the gravel content increases.
- ②. The side resistance of drilled **shafts** in gravels are generally under predicted by more than 100%.
- ③. When field results were compared to the Kulhawy, FHWA, and Meyerhof prediction equations, it was determined that.....

..... the Kulhawy method was the most conservative design equation and was not accurate when predicting capacities in dense material;

..... the F'HWA method under predicted resistance by 170 to 300% and should be modified for design in gravelly soils; and

..... the Meyerhof method under predicted resistance by 100 to 300% and should be doubled for gravels.

NOTE: Comprehensive results can be obtained by contacting the UDOT Research Division @ (801)965-4196; Refer to Report # UT-97.02. Titled: Drilled Shaft Side Friction in Gravelly Soils

